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Technical Support Report for Regulatory Action

U.S. Aircraft Fleet Projection and Engine Inventory to Year 2000

by

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February 1978

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Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air and Waste Management
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This report provides a forecast of the number of aircraft gas turbine engines which must comply with the proposed revisions to the EPA emissions standards. In providing this, it also supplies an aircraft forecast (useful if engines are changed on a given airframe) and a general engine forecast (useful if other revisions are proposed). This information may be used directly to obtain estimates of the total impact of various standards and implementation dates and more importantly, to obtain estimates of the total cost and cost effectiveness of the standards.

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INTRODUCTION

This report provides a forecast of the number of aircraft gas turbine engines which must comply with the proposed revisions to the EPA emissions standards. In providing this, it also supplies an aircraft forecast (useful if engines are changed on a given airframe) and a general engine forecast (useful if other revisions are proposed). This information may be used directly to obtain estimates of the total impact of various standards and implementation dates and, more importantly, to obtain estimates of the total cost and cost effectiveness of the standards. In view of the diverse uncertainties in forecasting, the reader is cautioned to treat this forecast as only a representative scenario whose accuracy is limited by the quality of the assumptions and judgments made in its derivation.

Derivation of the Projection

The EPA projection begins with a fleet projection provided by the FAA, Office of Aviation Policy (Reference 1). This unpublished projection (Table I) is an expansion in both time and detail of that provided in Reference 2. This projection gives the net fleet in five year increments broken down by categories of aircraft (e.g., 3-engine wide-body). This projection is created by econometric forecasting techniques derived from established relations between various parameters of economic activity and air carrier demand. The resulting demand for air service (in terms of passenger-miles) is converted to a fleet mix of aircraft through individual forecasts for each carrier with due consideration for the service patterns, frequencies of service, and profitability of the carriers. The shortcomings of this forecast for EPA use are fourfold. First, the forecast does not break down the categories (e.g., two-engine narrow-body) into specific aircraft types (e.g., DC-9). Second, the fleet is not presented in terms of categories defined by short, medium, or long haul. These limitations prevent a knowledge of the engine types in use in the fleet. Third, the forecast is in terms of the net only and there is no projection of the production and attrition which is necessary to separate the engines according to the standard complied with. Fourth, the data are presented in five year increments only, thus requiring interpolation.

The steps required to convert the FAA forecast into a useful projection for EPA purposes are discussed below.

(1) Interpolation to Provide Annual Fleet Numbers

For each category, the compounded annual rate of growth between each five year period is found and applied annually to the intervening years. This procedure is abandoned, however, during the period of start-up for a new category as, for instance, in the two-engine wide-body category. In this situation, it is more representative to ascribe a linear growth between the start-up date and the first FAA fleet projection. The annual net fleet size by category is presented in line group 3 of the fleet tables (Tables II and III).

(2) Attrition Rate

Attrition rate is difficult to project and in reality it would depend upon the profitability of the aircraft type in question, availability of replacement aircraft, environmental regulations, traffic demand, depreciation rate, maintenance experience, and the like. Such an analysis is well beyond the scope of this report and probably also beyond analysis anyway.

A crude approximation, but one which is nonetheless based upon one of the most influential effects, is to relate the attrition rate to the depreciation. It is common practice among U.S. airlines to write off an aircraft for tax purposes in 14 years. Thus, once the aircraft is written off, there are no more tax incentives available and the owner is more likely to replace it. Furthermore, tax laws strongly encourage this depreciation rate to be realistic or representative of the value of the aircraft. Thus, 15 years might be construed as a reasonable aircraft lifetime in the U.S. fleet.

It might further be argued that the financial climate of the airlines combined with the high price of replacement aircraft weighs against the rapid retirement of in-use aircraft. A possible alternative to the 15 year useful life is a 20 year useful life. A longer figure might be argued, but after 20 years there would typically be 60,000-70,000 hours on the airframe and maintenance costs would be climbing dramatically.

In summary, then, two attrition rates are considered, 15 years and 20 years, and are assumed to apply to all aircraft categories and types with one exception. The category of 4-engine narrow-body aircraft consists of the B707 family (including the B720) and the DC-8 family. For the time frame of interest neither of these aircraft will be produced for the U.S. fleet. Hence, the FAA forecast for this category and the interpolation procedure discussed in (1) define uniquely the attrition rate. This is the rate used for this category and roughly approximates a 20 year life per aircraft.

The attrition of each category is presented in line group 2 of the fleet tables, which include two scenarios, the 15 year lifetime (Table II) and the 20 year lifetime (Table III).

(3) Production Rate

The annual production in each category is found simply by the addition of that year's attrition and the net increase of that category in the fleet between the year in question and the next, and is presented in line group 1 of the fleet tables.

(4) Assignment of Fleet by Standards Complied With

The composition of the fleet by the standards with which it complies will change from year to year as older aircraft are phased out and newer

ones, meeting different standards, are added. Both the attrition line and the production line are subdivided according to the standard met. The standards to be met are those which will be proposed as revisions to the existing standards first promulgated in 1973, specifically,

a. 1981, HC and CO standards for newly manufactured engines,

b. 1984, NOx standard for newly manufactured engines in addition to those of (a),

c. 1985, HC and CO standards for in-use engines.

The net-in-fleet line is likewise subdivided according to the standard met (line group 3), giving for each year the summation of all the production minus all the attrition of aircraft in that category meeting each standard. A separate division for the retrofit rule (c) is not provided as the numbers can readily be taken from the pre-standards line for the year in question.

(5) Assignment of Fleet by Aircraft and Engine Type

At this stage, the projection supplies information on the numbers of aircraft by category (e.g., 4 engine wide body) and by standard met (e.g., 1981 newly manufactured engines). As yet, though, the specific aircraft types and more importantly the specific engines are not known. Finding this requires a number of assumptions, some based upon informed judgment, others made arbitrarily.

Certain assumptions bearing upon the issue were made in the FAA's original forecastand are presented in Table IV. Since the FAA forecast was made, however, the airlines and the airframe manufacturers have further refined their thoughts on the next generation of aircraft. As a consequence, an independent assessment was made. That resulted in the assumptions set forth in Table V. Some comment is necessary.

(a) Certain types of aircraft are not included (e.g., DC-10-40) because their contribution insofar as engine mix is concerned is expected to be small. The effect of engine changes among aircraft is to a large degree self conpensating anyway.

(b) The totally new aircraft which will appear are the Twin DC-10, the L1011-600, and the 2 and 3 engined versions of the B7S7 (essentially a narrow-body aircraft). The DC-X, B7X7, B7N7, and the A200 will not appear as the market would become excessively fragmented.

(c) Totally new aircraft will be brought into production in 1984. This date is unlikely to be correct precisely, but is expected to adequately reflect the situation.

(d) The remaining new aircraft will be growth or modified versions of existing types specifically the L1011-500, DC-9-S80, and the B737-200. Excessive fragmentation will prevent any more significant entries.

(e) The growth or modified aircraft will be brought into production in 1981. This is again a rough approximation to the real timetable.

(f) The introduction of the B7S7 will eliminate the B727 from production as they are basically competing aircraft.

Finally, there must be a number of arbitrary assumptions made, the issues at stake not being amenable to judgment at this time. These are presented in Table VI. In brief, these assumptions relate to the engines being utilized by the various aircraft types and to the distribution of types within each class. The major points are:

(a) Assignment of specific engines to specific airframes in most cases (e.g., JT9D with the B747).

This reflects the general situation that a single engine dominates in a given aircraft type. The error is to a degree self compensating. The major exception to this philosophy is the B7S7 wherein it was assumed that all three likely candidates would be used; this reflects the high degree of uncertainty involved.

(b) Before 1981, the L1011 and DC-10 families are represented exclusively by the L1011-100 and DC-10-10.

This simply approximates for convenience the actual case in which these aircraft dominates the pre-standards segment of that category.

(c) Retrofit of the 4-engine narrow-body aircraft with the CFM56 and the JT8D-209 equally.

This reflects the great uncertainty at this time. It is quite possible that both will indeed be used.

(d) Equal numbers of competing aircraft within each category.

It is not possible to weigh at this point the competitive advantages of each type over the others and the consequent numerical balance of each. Equal numbers of competing types within each category are therefore assumed as representing a reasonable balance.

Summary of the Results

It is now possible to use Table II or III to forecast the number of engines that must comply with each standard. The assumptions of Tables V and VI applied to Table II or III (these assumptions have been repeated on Tables II and III as footnotes for convenience) provide the necessary conversion from aircraft category to engine inventory. The 1981 newly manufactured engine totals can be taken from the middle of line group 3 in the Tables for the year 1984 (i.e., at the completion of the production run of engines subjected to the 1981 standards). The 1985 Retrofit totals are found in the first of line group 3 for the year 1985. The exception to this is the 4-engine narrow-body category, wherein the retrofit involves the use of newly manufactured engines and is therefore found in the second and third rows of line group 3 (Table II (c) or III (c)).

The 1984 newly manufactured engine standards present a more difficult situation for the period of compliance and hence the number of engines involved is indefinite. For the purposes of estimating cost effectiveness, it is postulated that a reasonable number of engines to consider is that over which the R&D, certification, and initial tooling costs (i.e., the fixed costs) would be amortized. Beyond this number, the cost would be reduced and the cost effectiveness increased unless, of course, those engine types are replaced by newly certificated engines for which the fixed costs would then be repeated. It is assumed here that the write-off period of the fixed costs constitutes 15 years of production (i.e., nearly to the end of the century). It may be argued that this is an unduly long period inasmuch as most of the engines in question were originally configured in the 1960's. Nonetheless, the high cost of development, the refinement of technology, and the timing of new technology (e.g., the NASA Energy Efficient Engine Program) suggests that the production of present engines and their derivatives will be assured for a long time. Thus, 15 years will be assumed.

Tables VII and VIII present the projection of the engine inventory for the two assumed attrition rates (15 and 20 years). These are only the engines that are "on the wing". In addition, there will be an inventory of spares amounting to 15-20% of those in actual use.

In view of the questions regarding the utility of the proposed NOx standard, it is also worthwhile to investigate the effect of eliminating the NOx (1984) standard. This elimination results in the 1981 standard being indefinite in duration and thus the 15 year amortization of fixed costs would apply to it. Table IX and X show the engine inventory in this case, again for the two assumed attrition rates.

Engine inventories of other postulated standards can be derived by simple modification of Tables II and III. The total annual production, attrition, and net-in-fleet figures are the same, however, different dates for implementation would require adjustments to the subdivisions (groupings by standards met). This is readily done once the specifics of the proposed standards are known.

References

1. "Air Carrier Fleet", Unpublished forecast, FAA, 1977.

2. "FAA Aviation Forecasts, Fiscal Years 1978-1989", FAA-AVP-77-32, September, 1977.

Table I

AIR CARRIER FLEET

(as of January 1)

	1977	1980	1985	1990	2000
Wide Body Jet					
4 Engine	106	138	241	302	552
3 Engine	202	232	463	704	1019
2 Engine	0	32	135	259	569
Standard Jet					
4 Engine	487	437	202	179	40
3 Engine	823	923	913	832	600
2 Engine	536	631	825	831	950
Turbo Prop					
4 Engine	69	51	31	18	10
2 Engine	178	160	130	77	25
Piston					
4 Engine	37	18	0	0	0
1 & 2 Engine	63	45	29	18	0
Total	2501	2667	2969	3220	3765

Table II - (a)

FLEET TABLE - 15 Year Attrition

Category: 2 Engine Narrow Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	30	32	33	35	0																				
1981 NME				0	85	88	90	0																	(1)
1984 NME							0	92	50	50	50	50	51	60	57	42	44	45	46	98	100	102	105		
Attrition																									
Pre-Standard				0	49	-	-	-	-	-	-	-	-	49	46	30	32	33	35	0					
1981 NME																			0	85	88	90	0		(2)
1984 NME																						0	92		
* Net in Fleet	536	566	598	631	666	702	741	782	825	826	827	828	829	831	842	853	865	877	889	900	913	925	937	950	
Pre-Standard	536	566	598	631	666	617	568	519	470	421	372	323	274	225	176	130	100	68	35	0					
1981 NME					0	85	173	263	-	-	-	-	-	-	-	-	-	-	-	263	178	90	0		(3)
1984 NME								0	92	142	192	242	292	343	403	460	502	546	591	637	735	835	937	950	

* As of January 1.

Before 1981: JT8D-17
1981 - 1983: JT8D-209, CFM56
1984 and after: JT8D-209, CFM56
CF6-32, JT10D, RB211-535

Table II - (b)

FLEET TABLE - 15 Year Attrition

Category: 3 Engine Narrow Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	32	33	98	61	0																				(1)
1981 NME				0	61	61	61	0																	
1984 NME							0	61	47	47	47	47	46	38	39	7	9	75	38	39	40	40	41		
Attrition																									
Pre-Standard	0	0	63	-	-	-	-	-	-	-	-	-	63	65	65	32	33	98	61	0					(2)
1981 NME																			0	61	61	61	0		
1984 NME																						0	61		
* Net in Fleet	823	855	888	923	921	919	917	915	913	897	881	865	849	832	805	779	754	730	707	684	662	641	620	600	
Pre-Standard	823	855	888	923	921	858	795	732	669	606	543	480	417	354	289	224	192	159	61	0					
1981 NME					0	61	122	183	-	-	-	-	-	-	-	-	-	-	-	183	122	61	0		(3)
1984 NME								0	61	108	155	202	249	295	333	372	379	388	463	501	540	580	620	600	

* As of January 1.

Before 1984: JT8D-17
1984 and after: CF6-32, JT10D, RB211-535

Table II - (c)

FLEET TABLE - 15 Year Attrition

Category: 4 Engine Narrow Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard																									(1)
1981 NME					(50)	(50)	(51)	(Retrofit)																	
1984 NME								(51)	(Retrofit)																
Attrition																									
Pre-Standard	17	17	16	47	47	47	47	47	0	0	3	10	10	14	14	14	14	14	14	14	14	14	13		(2)
1981 NME																									
1984 NME																									
* Net in Fleet	478	470	453	437	390	343	296	249	202	202	202	199	189	179	165	151	137	123	109	95	81	67	53	40	
Pre-Standard	478	470	453	437	390	293	196	98	0																(3)
1981 NME					0	50	100	151	-	-	151	148	138	128	114	100	86	72	58	44	30	16	2	0	
1984 NME								0	51	-	-	-	-	-	-	-	-	-	-	-	-	-	51	40	

* As of January 1.

Before retrofit: JT3D
After retrofit: CFM56, JT8D-209

Table II - (d)

FLEET TABLE - 15 Year Attrition

Category: 2 Engine Wide Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	6	13	13	20	0																				(1)
1981 NME				0	20	21	21	0																	
1984 NME							0	21	19	21	25	27	32	21	23	31	40	41	52	54	58	61	64		
Attrition																									
Pre-Standard															0	6	13	13	20	0					(2)
1981 NME																			0	20	21	21	0		
1984 NME																							21		
* Net in Fleet	0	6	19	32	52	72	93	114	135	154	175	200	227	259	280	303	328	355	383	415	449	486	526	569	
Pre-Standard	0	6	19	32	52	-	-	-	-	-	-	-	-	-	-	52	46	33	20	0					(3)
1981 NME					0	20	41	62	-	-	-	-	-	-	-	-	-	-	-	62	42	21	0		
1984 NME								0	21	40	61	86	113	145	166	189	220	260	301	353	407	465	526	569	

* As of January 1.

Before 1984: CF6-50
1984 and after: CF6-50, RB211-524

Table II - (e)

FLEET TABLE -15 Year Attrition

Category: 3 Engine Wide Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	10	10	10	34	0																				(1)
1981 NME				0	40	45	52	0																	
1984 NME							0	60	40	61	85	89	94	64	64	39	39	41	66	73	79	88	97		
Attrition																									
Pre-Standard									0	17	37	37	37	37	37	10	10	10	34	0					
1981 NME																			0	40	45	52	0		(2)
1984 NME																							60		
* Net in Fleet	202	212	222	232	266	306	351	403	463	503	547	595	647	704	731	758	787	816	847	879	912	946	982	1019	
Pre-Standard	202	212	222	232	266	-	-	-	-	266	249	212	175	138	101	64	54	44	34	0					
1981 NME					0	40	85	137	-	-	-	-	-	-	-	-	-	-	-	137	97	52	0		(3)
1984 NME								0	60	100	161	246	335	429	493	557	596	635	676	742	815	894	982	1019	

* As of January 1.

Before 1981: RB211-22B and CF6-6
1981 and after: RB211-22B, RB211-524, CF6-6, CF6-50

Table II - (f)

FLEET TABLE - 15 Year Attrition

Category: 4 Engine Wide Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	10	10	12	16	0																				(1)
1981 NME				0	18	21	23	0																	
1984 NME							0	25	26	27	27	28	28	34	36	21	32	36	42	45	59	54	57		
Attrition																									
Pre-Standard								0	15	15	15	15	15	15	16	10	10	12	16	0					(2)
1981 NME																			0	18	21	23	0		
1984 NME																						0	25		
* Net in Fleet	106	116	126	138	154	172	193	216	241	252	264	276	289	302	321	341	362	384	408	434	461	489	520	552	
Pre-Standard	106	116	126	138	154	-	-	-	154	139	124	109	94	79	64	48	38	28	16	0					(3)
1981 NME					0	18	39	62	-	-	-	-	-	-	-	-	-	-	-	62	44	23	0		
1984 NME								0	25	51	78	105	133	161	195	231	252	284	320	362	407	466	520	552	

* As of January 1.

Before 1981: JT9D-7
1981 and after: JT9D-7, JT9D-70

Table III - (a)

FLEET TABLE - 20 Year Attrition

Category: 2 Engine Narrow Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	30	32	33	35	0																				(1)
1981 NME				0	36	39	41	0																	
1984 NME							0	43	1	50	50	50	51	60	60	61	61	61	60	59	42	44	46		
Attrition																									
Pre-Standard									0	49	-	-	-	-	-	-	-	-	49	46	30	32	33	35	
1981 NME																									(2)
1984 NME																									
* Not in Fleet	536	566	598	631	666	702	741	782	825	826	827	828	829	831	842	853	865	877	889	900	913	925	937	950	
Pre-Standard	536	566	598	631	666	-	-	-	-	666	617	568	519	470	421	372	323	274	225	176	130	100	68	35	
1981 NME					0	36	75	116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(3)
1984 NME								0	43	44	94	144	194	245	305	365	426	487	548	608	667	709	753	799	

* As of January 1.

Before 1981: JT8D-17
1981 - 1983: JT8D-209, CFM56
1984 and after: JT8D-209, CFM56
CF6-32, JT10D, RB211-535

Table III - (b)

FLEET TABLE - 20 Year Attrition

Category: 3 Engine Narrow Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	32	33	35	0																					(1)
1981 NME				0	0	0	0	0																	
1984 NME							0	59	45	45	45	47	46	36	37	38	39	40	42	43	11	12	15		
Attrition																									
Pre-Standard			0	2	2	2	2	61	61	61	61	63	-	-	-	-	-	63	65	65	32	33	35	0	(2)
1981 NME																									
1984 NME																									
* Net in Fleet	823	855	888	923	921	919	917	915	913	897	881	865	849	832	805	779	754	730	707	684	662	641	620	600	
Pre-Standard	823	855	888	923	921	919	917	915	854	793	732	671	608	545	482	419	356	293	230	165	100	68	35	0	(3)
1981 NME																									
1984 NME									59	104	149	194	241	287	323	360	398	437	477	519	562	573	585	600	

* As of January 1.

Before 1984: JT8D-17
1984 and after: CF6-32, JT10D, RB211-535

Table III - (c)

FLEET TABLE - 20 Year Attrition

Category: 4 Engine Narrow Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard																									(1)
1981 NME					(50)	(50)	(51)																		
1984 NME								(51)																	
Attrition																									
Pre-Standard	17	17	16	47	47	47	47	47	0	0	3	10	10	14	14	14	14	14	14	14	14	14	13		(2)
1981 NME																									
1984 NME																									
* Net in Fleet	487	470	453	437	390	343	296	249	202	202	202	199	189	179	165	151	137	123	109	95	81	67	53	40	
Pre-Standard	487	470	453	437	390	293	196	98	0																(3)
1981 NME					0	50	100	151	-	-	151	148	138	128	114	100	86	72	58	44	30	16	2	0	
1984 NME								0	51	-	-	-	-	-	-	-	-	-	-	-	-	-	51	40	

* As of January 1.

Before retrofit: JT3D
After retrofit: CFM56, JT8D-209

Table III - (d)

FLEET TABLE - 20 Year Attrition

Category: 2 Engine Wide Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	6	13	13	20	0																				(1)
1981 NME				0	20	21	21	0																	
1984 NME							0	21	19	21	25	27	32	21	23	25	27	28	32	34	43	53	56		
Attrition																									
Pre-Standard																				0	6	13	13	20	(2)
1981 NME																									
1984 NME																									
* Net in Fleet	0	6	19	32	52	72	93	114	135	154	175	200	227	259	280	303	328	355	383	415	449	486	526	569	
Pre-Standard	0	6	19	32	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52	46	33	20	(3)
1981 NME					0	20	41	62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1984 NME								0	21	40	61	86	113	145	166	189	214	241	269	301	335	378	431	481	

* As of January 1.

Before 1984: CF6-50
1984 and after: CF6-50, RB211-524

Table III - (e)

FLEET TABLE - 20 Year Attrition

Category: 3 Engine Wide Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	10	10	10	34	0																				(1)
1981 NME				0	40	45	52	0																	
1984 NME							0	60	40	44	48	52	57	27	44	66	66	68	69	70	44	46	47		
Attrition																									
Pre-Standard														0	17	37	37	37	37	37	10	10	10	34	(2)
1981 NME																									
1984 NME																									
* Net in Fleet	202	212	222	232	266	306	351	403	463	503	547	595	647	704	731	758	787	816	847	879	912	946	982	1019	
Pre-Standard	202	212	222	232	266	-	-	-	-	-	-	-	-	-	266	249	212	175	138	101	64	54	44	34	(3)
1981 NME					0	40	85	137	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1984 NME								0	60	100	144	192	244	301	328	372	438	504	572	641	711	755	801	848	

* As of January 1.

Before 1981: RB211-22B and CF6-6
1981 and after: RB211-22B, RB211-524, CF6-6, CF6-50

Table III - (f)

FLEET TABLE - 20 Year Attrition

Category: 4 Engine Wide Body

Year	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	
Production																									
Pre-Standard	10	10	12	16	0																				(1)
1981 NME				0	18	21	23	0																	
1984 NME							0	25	11	12	12	13	13	34	35	36	37	39	41	43	38	41	44		
Attrition																									
Pre-Standard													0	15	-	-	-	-	15	16	10	10	12	16	(2)
1981 NME																									
1984 NME																									
* Net in Fleet	106	116	126	138	154	172	193	216	241	252	264	276	289	302	321	341	362	384	408	434	461	489	520	552	
Pre-Standard	106	116	126	138	154	-	-	-	-	-	-	-	-	154	139	124	109	94	79	64	48	38	28	16	(3)
1981 NME					0	18	39	62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1984 NME								0	25	36	48	60	73	86	120	155	191	228	267	308	351	389	430	474	

* As of January 1.

Before 1981: JT9D-7
1981 and after: JT9D-7, JT9D-70

Table IV

VARIABLES AND ASSUMPTIONS EMPLOYED
IN THE FAA FORECAST

Variable	Assumptions
Revenue Passenger miles	Economic assumptions are the same as those used in the air carrier demand model (Reference 2).
Average seating capacity	Average seating capacity will increase by about 4 seats per year as air carriers attempt to reduce the cost per seat-mile by purchasing more wide-body aircraft and adding seats to the existing fleet.
Average stage-length	Average stage-length will increase by about 3 miles per year.
Aircraft Type	
- Two-engine	Continued introduction of DC-9 and 737 (both new and purchased from truck carriers) into local service carrier fleets.
	Replacement of remaining turboprops with twin engine standard-body aircraft in late 1970s.
	Introduction of a new wide-body aircraft in early 1980s.
- Three-engine	Continued introduction of wide-body aircraft and 727-200.
	Introduction of new aircraft in early 1980s with seating capacity between 727-200 and wide-body aircraft.
	Appearance of stretch versions of present wide-body aircraft in the mid-1980s.
- Four-engine	Continued retirement of nonfan and older fan-jet aircraft.
	Continued introduction of present wide-body aircraft.
Passenger Load Factor	A gradual increase in the load-factor from the present 55 percent to 58 percent by the early 1980s and then remaining at this level through the forecast period.

Table V

JUDGMENTAL ASSUMPTIONS EMPLOYED IN EPA PROJECTION

Aircraft Category	Assumption
4 Engine Wide Body	B747 family exclusively
3 Engine Wide Body	L1011-100,-200,-500 DC-10-10,-30
2 Engine Wide Body	A300 B1,-B2 (after 1978) Twin DC-10 (after 1984) L1011-600 (after 1984)
4 Engine Narrow Body	B707, B720 DC-8
3 Engine Narrow Body	B727-200 (up to 1984) B7S7, 3 engine (after 1984)
2 Engine Narrow Body	DC-9-30 B737-200 DC-9-S80 (after 1981) B737-300 (after 1981) B7S7, 2 engine (after 1984)

Table VI

ARBITRARY ASSUMPTIONS EMPLOYED IN EPA PROJECTION

Aircraft Category	Assumptions
4 Engine Wide Body	(1) JT9D engines dedicated exclusively to the B747 fleet.
	(2) JT9D-7 produced exclusively prior to 1981.
	(3) Equal number of JT9D-7 and -70 models produced after 1981.
3 Engine Wide Body	(1) Equal numbers of L1011-100 and DC-10-10 produced exclusively prior to 1981 (using RB211-22B and CF6-6, respectively).
	(2) Equal numbers of L1011-100, L1011-200 and 500 together, DC-10-10, and DC-10-30 produced after 1981 (using the RB211-22B, RB211-524, CF6-6, and CF6-50, respectively).
2 Engine Wide Body	(1) A300 B1 or B2 produced exclusively prior to 1984 (using CF6-50).
	(2) Equal numbers of A300, Twin DC-10, and L1011-600 produced after 1984 (using in the first two cases the CF6-50 and in the last, the RB211-524).
4 Engine Narrow Body	(1) All aircraft retrofitted with equal numbers of CFM56 and JT8D-209 engines by 1985 to meet EPA and FAA environmental standards.
3 Engine Narrow Body	(1) B727-200 produced exclusively to 1984 (JT8D-17).
	(2) A three engined version of the B7S7 utilizing a clipped fan high-bypass engine is produced exclusively after 1984.
	(3) The clipped fan engine is represented by equal numbers of the CF6-32, JT10D, and RB211-535.
2 Engine Narrow Baody	(1) Prior to 1981, the aircraft are various models of the DC-9 and B737, and the propulsion is represented by the JT8D-17 for emissions purposes.
	(2) Between 1981 and 1984, the aircraft produced are the DC-9-S80 (JT8D-200 series) and B737-300 (CFM56).
	(3) After 1984, the production is equally divided between the short haul (DC-9-S80 and B737-300 in equal numbers) and the short/medium haul (B7S7, twin engine version powered in equal numbers by the three clipped fan engines). The DC-9-S80 is powered by the JT8D-209 and the B737-300 by the CFM56.

Table VII

ENGINE INVENTORY
(15 year attrition rate)

	Standard		
Engine	1981	1985 Retrofit	1984*
JT8D-17	549	2947	0
JT8D-209	264	302	570**
JT9D-7	124	616	1040
JT9D-70	124	0	1040
JT10D	0	0	933
CF6-6	105	399	738
CF6-50	226	104	1437
CF6-32	0	0	933
CFM56	262	302	570**
RB211-22B	102	399	738
RB211-524	102	0	1085
RB211-535	0	0	932

* 15 years of production (to 1999).

** These numbers include 102 engines newly built in 1984 to be retrofitted onto the B707 and DC-8 fleet for compliance with the 1985 Retrofit Rule. Although these engines exceed the requirements specified by the rule, their date of manufacture forces them to comply with the more stringent standards (see Table II(c)).

Table VIII

ENGINE INVENTORY
(20 year attrition rate)

	Standard		
Engine	1981	1985 Retrofit	1984*
JT8D-17	0	3894	0
JT8D-209	116	302	478**
JT9D-7	124	616	860
JT9D-70	124	0	860
JT10D	0	0	837
CF6-6	105	399	600
CF6-50	226	104	1177
CF6-32	0	0	836
CFM56	116	302	478**
RB211-22B	102	399	600
RB211-524	102	0	888
RB211-535	0	0	836

* 15 years production (to 1999).

** These numbers include 102 engines newly built in 1984 to be retrofitted onto the B707 and DC-8 fleet for compliance with the 1985 Retrofit Rule. Although these engines exceed the requirements specified by the rule, their date of manufacture forces them to comply with the more stringent standards (see Table III(c)).

Table IX

ENGINE INVENTORY
NO 1984 STANDARD
(15 year attrition rate)

	Standard	
Engine	1981 NME*	1985 Retrofit
JT8D-17	549	2947
JT8D-209	582	404
JT9D-7	848	616
JT9D-70	848	0
JT10D	713	0
CF6-6	660	399
CF6-50	1254	104
CF6-32	713	0
CFM56	582	404
RB211-22B	660	399
RB211-524	893	0
RB211-535	713	0

* 15 years production (to 1996).

Table X

ENGINE INVENTORY
NO 1984 STANDARD
(20 year attrition rate)

	Standard	
Engine	1981 NME*	1985 Retrofit
JT8D-17	0	2947
JT8D-209	420	404
JT9D-7	740	616
JT9D-70	740	0
JT10D	723	0
CF6-6	588	399
CF6-50	1106	104
CF6-32	721	0
CFM56	420	404
RB211-22B	582	399
RB211-524	885	0
RB211-535	721	0

* 15 years production (to 1996).